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Three-Dimensional Measurement of Electron Temperature and Density in a Split Ring Resonator Microplasma

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Overview

This study investigated the three-dimensional characteristics of an argon microplasma in order to properly design a miniature ion thruster. The microplasma was created using a Split Ring Resonator (SRR) device previously studied at UAH [1]. The SRR is manufactured by etching the chosen ring design onto a copper-dielectric laminate (Fig. 1). Langmuir probes are used to calculate electron temperature and plasma density. This was done for 100 evenly-spaced points in a 0.9inx0.9in 2D grid over the SRR. With the 2D data, theoretical performance measurements were calculated for an ion thruster with the same screen grid height as the 2D scan. The 2D grid measurements were then repeated for a total of four different heights above the SRR and the resulting theoretical performance measurements were compared.

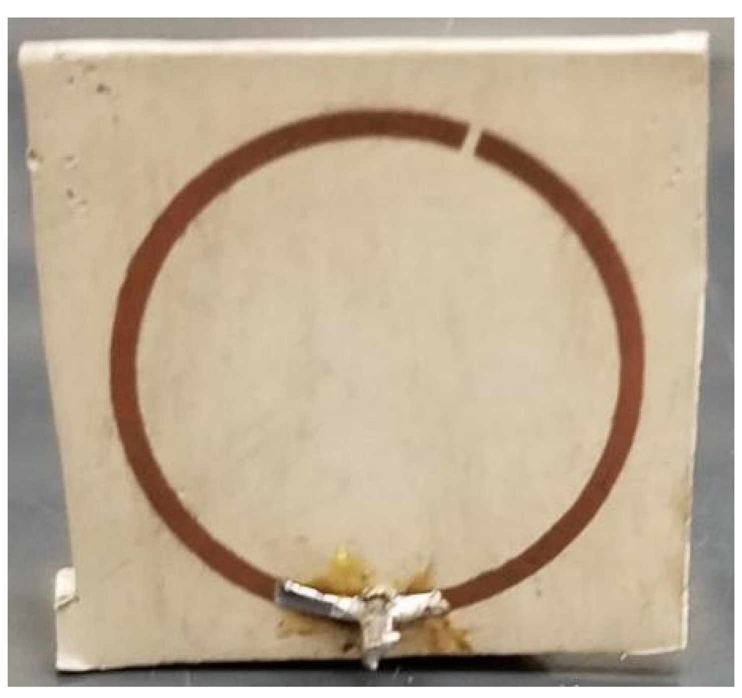

Fig. 1 – Inactivated SRR

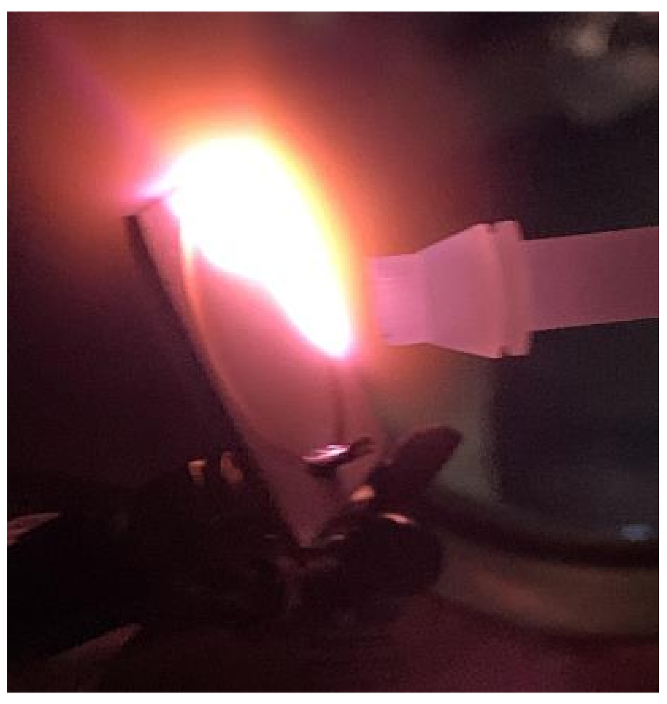

Fig. 2 – SRR Argon Plasma

Conceptual Framework

When the correct frequency signal is transmitted through the SRR, a large voltage difference is achieved at the gap, leading to ionization and creation of a plasma (Fig. 2). The Langmuir probes create a current-voltage (I-V) for each individual grid point in the plasma. The four free fitting parameter method [2] is then used in combination with the Druyvesteyn method as presented in [3] to calculate electron temperature and plasma density. Using average electron temperature and plasma density over the whole 2D data set, theoretical thrust and specific impulse can be calculated. The theoretical thrust and specific impulse are for a miniature gridded ion thruster design with grid placement at the tested height.

References

1. R. Dextre, K. G. Xu, *IEEE Transactions on Plasma Science,* vol. 45, no. 2, 2017.
2. A. A. Azooz, *Review of Scientific Instruments*, 79, 103501, 2008.
3. V. A. Godyak, V. I. Demidov, *Journal of Physics D: Applied Physics,* 44, 269501, 2011.

Key Findings/Results

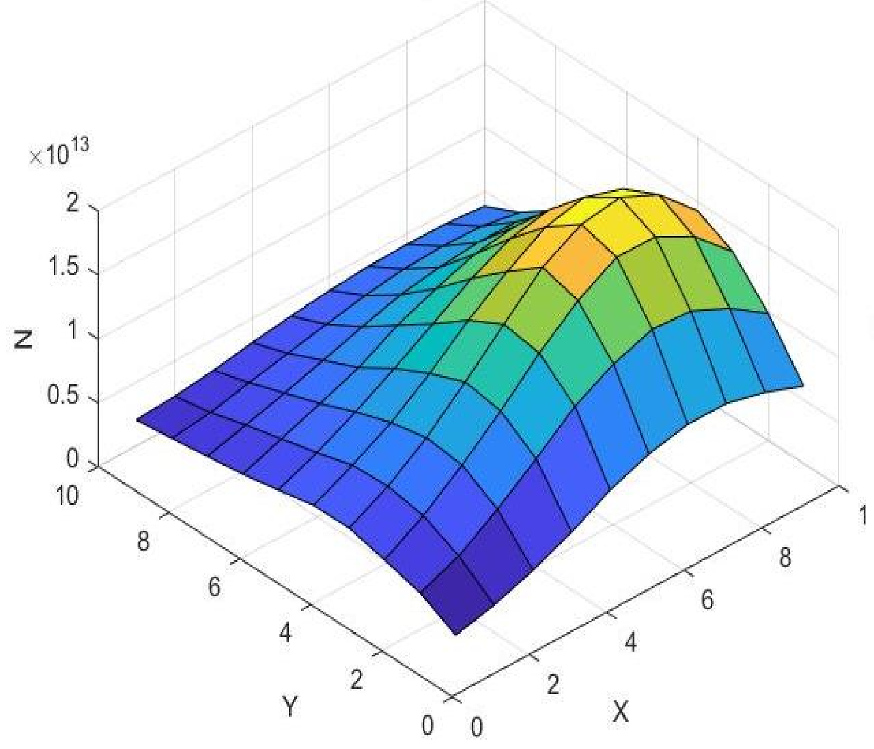

Fig. 3 – 2D Plasma Density at 0.5in above SRR

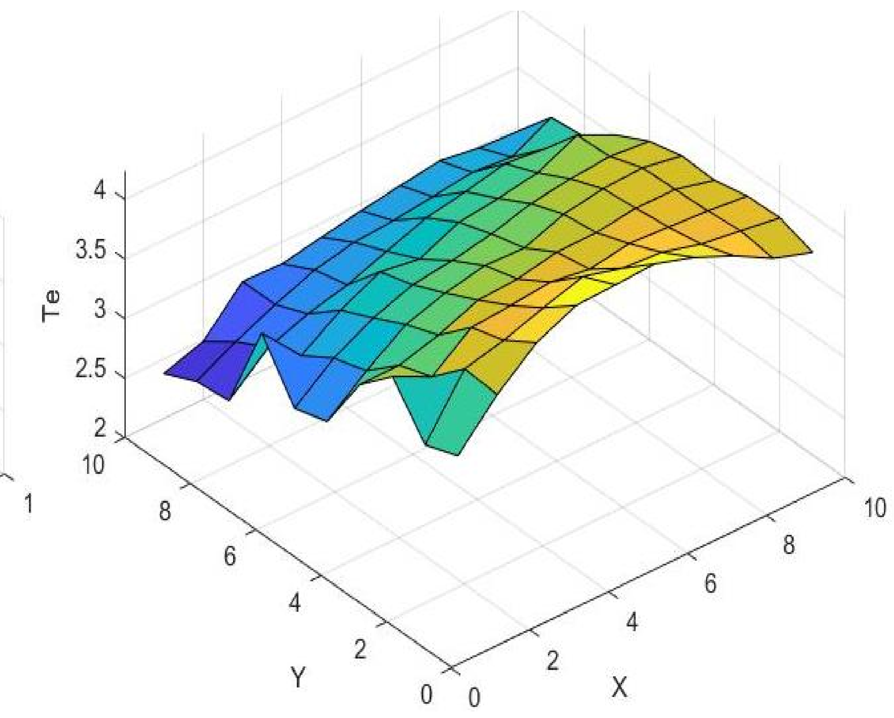

Fig. 4 – 2D Electron Temperature at 0.5in above SRR

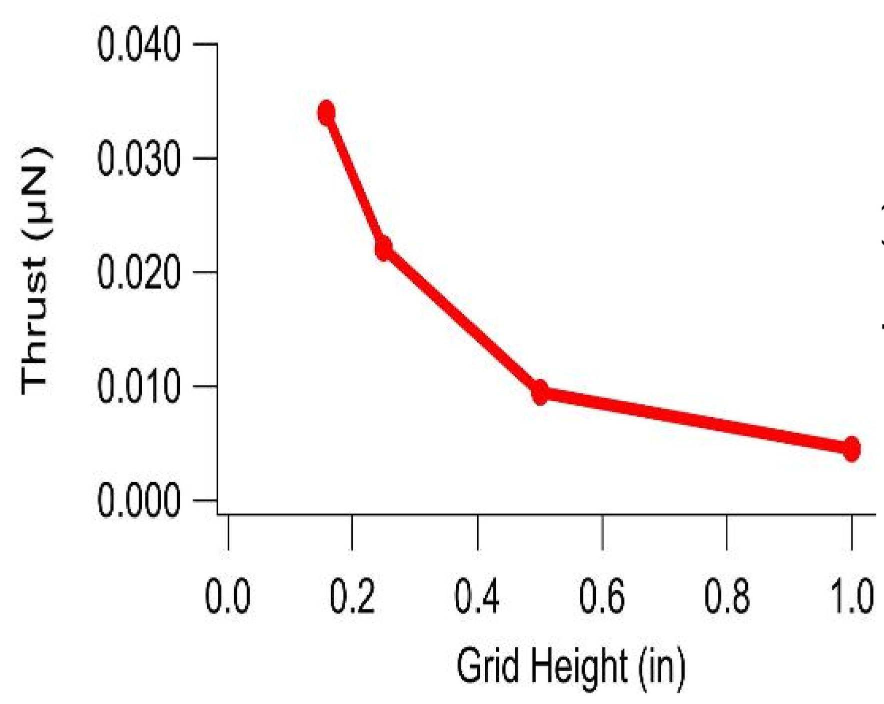

Fig. 5 – Theoretical Thrust (μN) for each height.

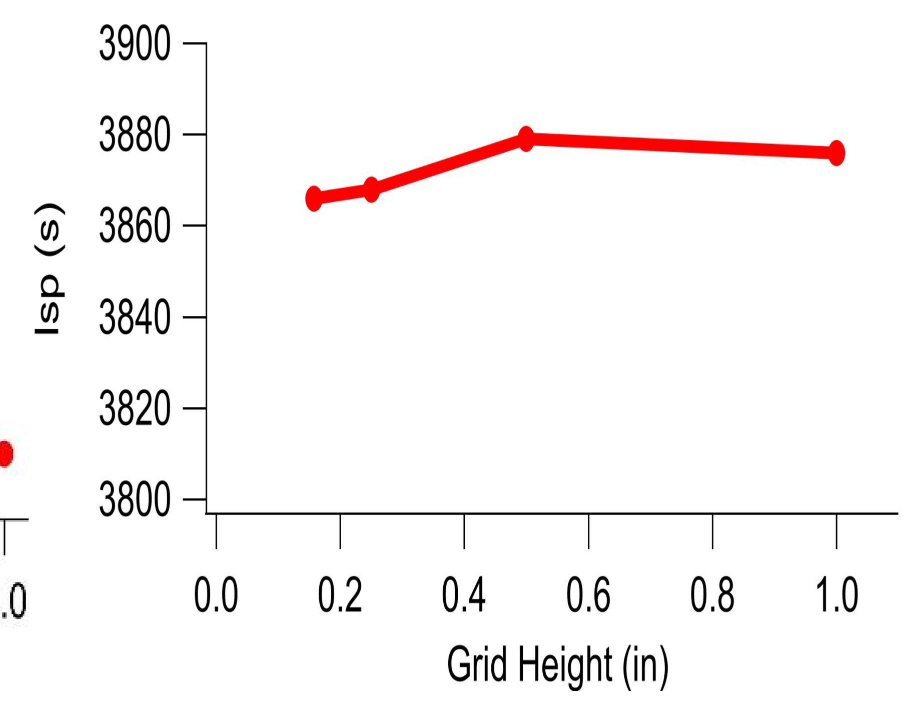

Fig. 6 – Theoretical Specific Impulse (s) for each height.

When comparing the average plasma densities for each height scan (sample shown in Fig. 3), a strong trend is found showing decreasing density with increased height. The average electron temperatures (sample shown in Fig. 4) show a peak at 0.5in. Theoretical thrust is shown to decrease with increased height (Fig. 5). Theoretical specific impulse is shown to be relatively constant at any height level, being around 3870s. Based on this data alone, it can be concluded that the optimal grid height for an SRR powered miniature ion thruster is as close to the SRR as is physically limited.

Impact

Using these results, an improved miniature ion thruster can be designed with the ultimate goal of micro-satellite propulsion. Such a propulsion system could yield reasonable thrust levels with high electrical efficiency, a perfect candidate for giving Cube-Sats orbital maneuvering capability.

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